

## PERSPECTIVE

## Contrast sensitivity testing in clinical practice

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A survey of ophthalmic publications carried out using the Medline database revealed that during 1983 the search terms *contrast* and *sensitivity* appeared in immediate conjunction within the indexing fields of 74 publications. By 1993, this figure had risen to 325. Though a search conducted in this manner would by no means retrieve all the relevant publications, this fourfold increase would suggest a rapidly emerging field of study. Yet, it is a contention of this perspective that contrast sensitivity testing has, despite the ready availability of apparatus and charts adapted for clinical use, had little or no impact on routine ophthalmic practice. Here we explore the reasons why this test has not fulfilled the role that some had predicted for it. Attention is then focused on those circumstances where assessment of this visual capacity is considered appropriate and an attempt is made to classify the assortment of tests now available for clinical use. Future developments are discussed.

**Background**

Humans inhabit a richly patterned visual environment and it is upon our capacity to interpret spatial information (visual detail) that our ability to see is most dependent. It is therefore not surprising that our most widely used index of sight, visual acuity, is a measure of spatial resolving power. Yet, putting to one side other stimulus dimensions such as colour and movement, most objects viewed in everyday life vary in intensity – quite unlike the fixed, high contrast optotypes traditionally found on acuity test charts.

The clinical relevance of visual sensitivity to contrast was first appreciated in the last century.<sup>1</sup> Indeed, though its use did not become widespread, a practical test of contrast sensitivity was first described in the second volume of this journal published in 1918.<sup>2</sup> Yet, a true understanding of the role that contrast plays in the visual discrimination of form was not forthcoming until the innovative studies of Campbell and his colleagues at Cambridge in the mid 1960s. Two aspects of their work presaged the re-emergence of contrast sensitivity testing in clinical practice. Firstly, the counter-intuitive finding that we are able to see, at least at contrast threshold and for simple sinusoidal gratings, targets of 'medium' resolution better than those of either low or high resolution – the *contrast sensitivity function*.<sup>3</sup> This led to the notion that testing contrast sensitivity over a range of target resolutions (spatial frequencies) provides a more comprehensive evaluation of spatial visual function than does visual acuity which, it should be remembered, is in effect a measure of contrast sensitivity for the smallest target the observer can identify. Secondly, the contrast sensitivity function appeared to be subserved by a series of neural channels each responding to detail of a relatively narrow size range (bandwidth).<sup>4,5</sup> Damage within the visual pathway, might, it was thought, selectively inhibit sensitivity within one or more of the underlying channels.<sup>6</sup>

Faced with a 'new' method which provided a more

comprehensive measure of spatial vision and which, at least in theory, had the potential to reveal anomalies of visual function hitherto undocumented, the research community was quick to develop a plethora of practical tests of contrast sensitivity and to seek out their clinical applications. Much of the work arising could best be categorised as 'descriptive' in nature – investigators seeking to answer the quite legitimate question 'In what ocular (and indeed systemic) conditions is contrast sensitivity diminished and in what manner?' It serves no useful purpose to review here the numerous studies of this kind – suffice it to point out that loss of contrast sensitivity has been associated with a gamut of clinical circumstances ranging from renal failure<sup>7</sup> to radial keratotomy.<sup>8</sup> Leguire<sup>9</sup> has tabulated the type of sensitivity loss characteristic of the major ophthalmic conditions. With the benefit of hindsight it may appear barely remarkable that patients with visual disorders should show deficits on a test which measures seeing ability. Yet, no doubt these investigators were hopeful that particular categories of eye disease might be characterised by diagnostically specific sensitivity losses. Unfortunately this turned out not to be the case and although average sensitivities were often shown to be lower in diseased eyes these findings are, from the clinical viewpoint, only applicable to groups. Clinicians, however, manage *individual* patients about which they need to muster information. Given this situation, under what circumstances and under what manner of test conditions may the clinician usefully employ a test of contrast sensitivity?

**Guidelines for clinical testing**

One of the earliest predicted roles for modern contrast sensitivity tests was that of screening, principally for glaucoma<sup>10</sup> and indeed such use has continued to be mooted up until quite recently.<sup>11</sup> Yet, the poor sensitivity and specificity of all simple tests of contrast sensitivity (that is, those not involving chromatically or temporally modulated targets) has severely impeded their application in this area to the point at which their use has been described as 'hopelessly optimistic', even by those who formally propounded the screening role.<sup>12</sup>

A second major area where contrast sensitivity testing has been ascribed a clinical role is in patient management. Here, it is necessary to express at the outset the practical relation between a test of visual acuity and that of contrast sensitivity. While it has not always been the case<sup>13</sup> it is now almost universally agreed that contrast sensitivity testing is *always supplementary* to acuity determination. Further, there appears to be no benefit in the testing of contrast sensitivity for clinical management *except where acuity is found to be normal or near normal*.<sup>14</sup> A decision to determine a patient's contrast sensitivity need only be undertaken in order to reduce *uncertainty* within the clinical picture. Perhaps the most illustrative, albeit rare, example is that of the patient with cataract, typically subcapsular, whose visual complaints

appear disproportionate to their recorded acuity.<sup>15</sup> Here there exist a priori grounds for suspecting that impaired contrast sensitivity may be the basis of the underlying complaint for we already know that the image degradation in this condition arises from a loss of physical contrast on the retina because of forward light scatter. Should a sensitivity loss be confirmed, then the symptomatology no longer appears to conflict with the examination and other test results.\* In such a situation considerable insight may be gained into the problems the patient actually experiences, in effect one now has a measure which tells us how close the patient's threshold sensitivity is in relation to the physical contrast of real world objects ('contrast reserve').<sup>17</sup> For example, although a patient's sensitivity might be sufficient to identify someone's face, if their threshold is only slightly above that required for such a task, they may still experience real visual disability.

Once the decision to test has been made one must decide whether to use a target of unitary spatial frequency (or relatively narrow range in the case of targets other than gratings), or to test at low, medium (corresponding to maximum or 'peak' sensitivity), and high spatial frequencies – in effect to sample all regions of the contrast sensitivity function. Certainly the latter proposal has its adherents<sup>18</sup> who claim that this is necessary in order to evaluate properly the extent of visual loss arising from diminished sensitivity to contrast. While testing in this manner no doubt provides the most comprehensive description of visual performance, it is now generally thought to be superfluous to undertake testing at high or low spatial frequencies and that testing should focus on or around the region of peak sensitivity<sup>14</sup> (approximately 2 to 4 cycles per degree). This is justified primarily on theoretical grounds that contrast sensitivity for high spatial frequency targets (that is, those beyond the region of peak sensitivity) will be highly correlated with visual acuity (even though the relative magnitude of a contrast sensitivity loss may be greater than that for acuity). Similarly, a loss of contrast sensitivity for low spatial frequency targets in the absence of a loss in the region of peak sensitivity is theoretically implausible and claims contrary to this are more likely to be found in sales literature than more traditional sources of learning.

Another issue about which test users need to be aware is that of reliability (reproducibility). That a test can provide a precise numerical score says nothing about this important issue. Unfortunately poor reliability (that is, a high probability that a measured change in test score will occur over time which cannot be attributable to a change in a patient's condition) is a common finding among tests of contrast sensitivity.<sup>19, 20</sup>

#### Classification of contrast sensitivity tests

We have already discussed arguments for and against testing at single versus multiple spatial frequencies and this is one of several means by which tests of contrast sensitivity may be classified. Others include the nature of the target(s) presented (for example, sine wave or square wave gratings, or optotypes), the formal manner of test presentation (hard copy or screen based), and test methodology (for example, forced choice, method of limits).

That one has the option to choose a variety of target descriptions is of both theoretical and practical significance. The nature of the target will reflect the absolute sensitivity

recorded; although one can, under most circumstances, compare visual acuities obtained with, say, Landolt C or Snellen optotypes this is not the case with contrast sensitivity. In the clinical domain, tests of contrast sensitivity can be categorised into those using grating targets (either sine or square wave) and those employing traditional optotypes. The theoretical basis (including the mathematical description of contrast itself) differs so greatly between these test types that it is judicious to refer separately either to *grating* or *letter* contrast sensitivity. Indeed it has been suggested that tests employing optotypes should not be referred to as tests of contrast sensitivity at all.<sup>9</sup> This is because it is not possible to test at discrete spatial frequencies owing to the spatial complexity of these targets, rather they are designed such that their spatial frequency content consists of a narrow range of frequencies. Unfortunately, the use of optotypes demands that a further classification be invoked – namely, that of *low contrast letter acuity*† in which one aims to determine primarily the smallest recognisable optotype (acuity) for a range of contrasts.<sup>9, 22</sup> In practice, the proponents of letter contrast sensitivity and low contrast letter acuity view these tests as complementary and in the final analysis each in its own way attempts to measure 'sensitivity to contrast'.<sup>23</sup> On a practical level, owing to general familiarity with the nature of the task, letter contrast sensitivity testing usually proceeds uneventfully and without the need for time consuming explanation. On the other hand, tests involving the presentation of gratings are relatively novel and testers need to be aware that this complexity can translate into perplexity on the part of the patient.

Classification based on the format of target presentation divides tests into those which are screen based (and by this we mean systems under microprocessor control with targets presented on cathode ray tube displays) and those in which the test targets are printed on to a chart not dissimilar to traditional acuity tests. In screen based tests, both spatial frequency and contrast dimensions may be sampled, within limits, at whatever resolution one chooses, though very high contrasts can be difficult to achieve. However, in the light of the arguments put forward in the preceding section, testing at multiple spatial frequencies may only elicit redundant information, added to the fact that as the number of test frequencies is increased so does the length of the test procedure. Practical disadvantages of screen based tests include the need for frequent calibration and the general complexity of the test procedure by comparison with hard copy charts. Though screen based systems are commercially available their role is more generally suited to experimental studies (either basic or clinical) rather than routine use. In hard copy tests, each contrast step for each spatial frequency occupies chart space and therefore, without resorting to a multiplicity of charts, the test designer must opt for a limited range of contrasts and target resolutions. While for reasons already stated, a limited range of spatial frequencies may not handicap clinical testing, it is necessary that the range of contrast available is sampled appropriately – that is, in sufficiently fine steps so as to maximise sensitivity to detect change.<sup>24</sup>

Test methodology refers to the psychophysical procedure by which targets are presented and threshold sensitivity determined. It is generally agreed that so-called forced choice procedures provide the highest level of reliability<sup>25</sup> but against this they tend to be least favoured by patients who are generally averse to speculating upon the presence of a target which is clearly below their detection threshold. Furthermore, there is a need for greater awareness that just because

\*Even here, though, a word of caution needs to be sounded as we know that light scatter (glare) may only arise within illuminated surroundings characteristic of the outside world as opposed to the darkened consulting room. It may therefore be necessary to repeat both acuity and contrast sensitivity measurement in high ambient illumination or in the presence of a glare source.<sup>16</sup>

†Unfortunately, synonyms abound even at this level of categorisation: *contrast visual acuity* being but one example.<sup>21</sup>

two tests look alike, or use the same psychophysical procedure, they may not correlate highly. For example, in an extensive study of colour vision deficiencies in diabetic retinopathy using many different tests Aspinall<sup>26</sup> showed by factor analysis that 'each test measures something unique to itself' – definitions of contrast sensitivity loss are therefore highly test dependent.

### Future developments

We have already discussed the limited role that contrast sensitivity testing may play in routine clinical practice and that in essence its limitations arise from its inability to document a visual loss not revealed by simpler means of testing. Are there perhaps ways in which the screening or diagnostic specificity of the test may be improved? In an attempt to answer this question a number of more sophisticated test variants have been proposed and are currently undergoing evaluation. Principal among these is the use of coloured or flickering (temporally modulated) targets. Many British ophthalmologists will themselves have undergone a test of colour contrast sensitivity pioneered in Britain by Arden and his co-workers and used to quantify the purported loss of visual function found in operators of certain ophthalmic lasers.<sup>27</sup> Clearly, this is an example of a niche role well outside the routine. However, although deficits of colour contrast sensitivity and of contrast sensitivity with flickering targets have been reported to be of value in detecting early visual loss in glaucoma,<sup>12 28–29</sup> it is too early to predict their likely impact.

### Conclusion

Experience has shown that while there has been a historical awareness of the contribution that contrast sensitivity testing may make to the practice of ophthalmology, there remains confusion over its present role. While diminished sensitivity to contrast is characteristic of the visual loss experienced by many patients with ocular disease, at least for tests involving stationary, achromatic targets (that is, all those currently commercially available) this finding is seldom of practical benefit to the clinician. Where contrast sensitivity testing is able to clarify the clinical picture, it is supplemental to traditional acuity testing – that is, applicable only to patients with normal or near normal visual acuity. Confusion has also arisen owing to the use of 'contrast sensitivity' as a generic term to describe many different tests whose application and use may differ quite considerably. The classification and system of nomenclature adopted here should clarify the nature of the available tests. New sophisticated test variants involving temporally and chromatically modulated targets have shown initial promise in screening for glaucoma. Those who use contrast sensitivity tests in clinical practice need to be critical not only of what the test is actually measuring but of what value is the derived measurement to their decision

making for patient management. While redundant information can have value in some situations, such as language, in the clinical context it is costly!

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